Equipment Service Life Revisited

CAIS User Group Meeting
Las Vegas, Nevada

April 12, 2006

Lawrence Livermore National Laboratory
Whitestone Research

Project Overview

- NNSA-funded project to analyze extended equipment service lives in partnership with LLNL
- Estimating capital expenditures relies on accurate service life assumptions
- Errors in service life result in misallocation of scarce funds
- Actual experience at LLNL suggests service lives of equipment exceeding those of current CAIS guidance

Project Milestones

- 2/05 Kickoff, LLNL
- 3/05 Prototype Survivor Curves, WST
- 5/05 Methods Review, WST
- 10/05 Preliminary Results, WST
- 1/06 Draft Results Presentation, LLNL
- 3/06 Revised Draft Results Presentation, LLNL
- 4/12/06 CAIS Meeting Presentation, NTS
- 6/06 Final Report to NNSA

LLNL equipment renewal costs are substantially lower than comparative experience

Annual Maintenance Renewal per Replacement Value	
Site/Model	**Annual Renewal/RPV**
LLNL	0.5%
APPA Strategic Reinvestment Model	2.0%
Brigham Young University	2.0%
Whitestone MARS Model	1.2%
Kansas City Plant	1.9%

Source: LLNL

Hypothesis: Extending service life reduces maintenance costs

- Forecast service life with equipment condition verification
- Consistent maintenance extends wear out failures
- Renewal decisions should be made on failure distribution, not average service life
- Traditional service life determinations ignore equipment still in use

Literature on equipment life

- Survivor curve analysis used for computing equipment service lives (Winfrey, 1935)
- ASHRAE published survey-based life tables since 1978, but discredited by Hiller (2000)
- Secondary sources are imprecise (R.S. Means, Whitestone)
- ASHRAE/ORNL demonstrates survivor curve methods (Abramson, 2005)

ASHRAE survey-based service lives

Table 3 Estimates of Service Lives of Various System Components[a]

Equipment Item	Median Years	Equipment Item	Median Years	Equipment Item	Median Years
Air conditioners		Air terminals		Air-cooled condensers	20
Window unit	10	Diffusers, grilles, and registers	27	Evaporative condensers	20
Residential single or split package	15	Induction and fan-coil units	20	Insulation	
Commercial through-the-wall	15	VAV and double-duct boxes	20	Molded	20
Water-cooled package	15	Air washers	17	Blanket	24
Heat pumps		Ductwork	30	Pumps	
Residential air-to-air	15[b]	Dampers	20	Base-mounted	20
Commercial air-to-air	15	Fans		Pipe-mounted	10
Commercial water-to-air	19	Centrifugal	25	Sump and well	10
Roof-top air conditioners		Axial	20	Condensate	15
Single-zone	15	Propeller	15	Reciprocating engines	20
Multizone	15	Ventilating roof-mounted	20	Steam turbines	30
Boilers, hot water (steam)		Coils		Electric motors	18
Steel water-tube	24 (30)	DX, water, or steam	20	Motor starters	17
Steel fire-tube	25 (25)	Electric	15	Electric transformers	30
Cast iron	35 (30)	Heat exchangers		Controls	
Electric	15	Shell-and-tube	24	Pneumatic	20
Burners	21	Reciprocating compressors	20	Electric	16
Furnaces		Package chillers		Electronic	15
Gas- or oil-fired	18	Reciprocating	20	Valve actuators	
Unit heaters		Centrifugal	23	Hydraulic	15
Gas or electric	13	Absorption	23	Pneumatic	20
Hot water or steam	20	Cooling towers		Self-contained	10
Radiant heaters		Galvanized metal	20		
Electric	10	Wood	20		
Hot water or steam	25	Ceramic	34		

Notes: 1. ASHRAE makes no claims as to the *statistical* validity of any of the data presented in this table.
2. Table lists base values that should be adjusted for local conditions (see the section on Service Life).

Source: Data obtained from a survey of the United States by ASHRAE Technical Committee TC 1.8 (Akalin 1978).

[a] See Lovvorn and Hiller (1985) and Easton Consultants (1986) for further information.
[b] Data updated by TC 1.8 in 1986.

ASHRAE/ORNL survivor curve analysis for office sample

Equipment Type	Median Service Life (Yrs)	Total No. of Units	No. of Units Replaced
Air Handling Units	>52	1324	79
DX Air Distribution Equipment	>24	1907	284
Centrifugal Chillers	>25	234	34
Metal Cooling Towers	>22	170	24
Steel Gas-Fired Boilers	>22	117	24
Pneumatic/Hybrid Control Systems	>18	101	25
Electronic/DDC Control Systems	>7	68	6
Electric Potable Water Heaters	>21	304	36

Source: Abramson, 2005

LLNL Historical Equipment Database

Many observations over time (N = 24,883)

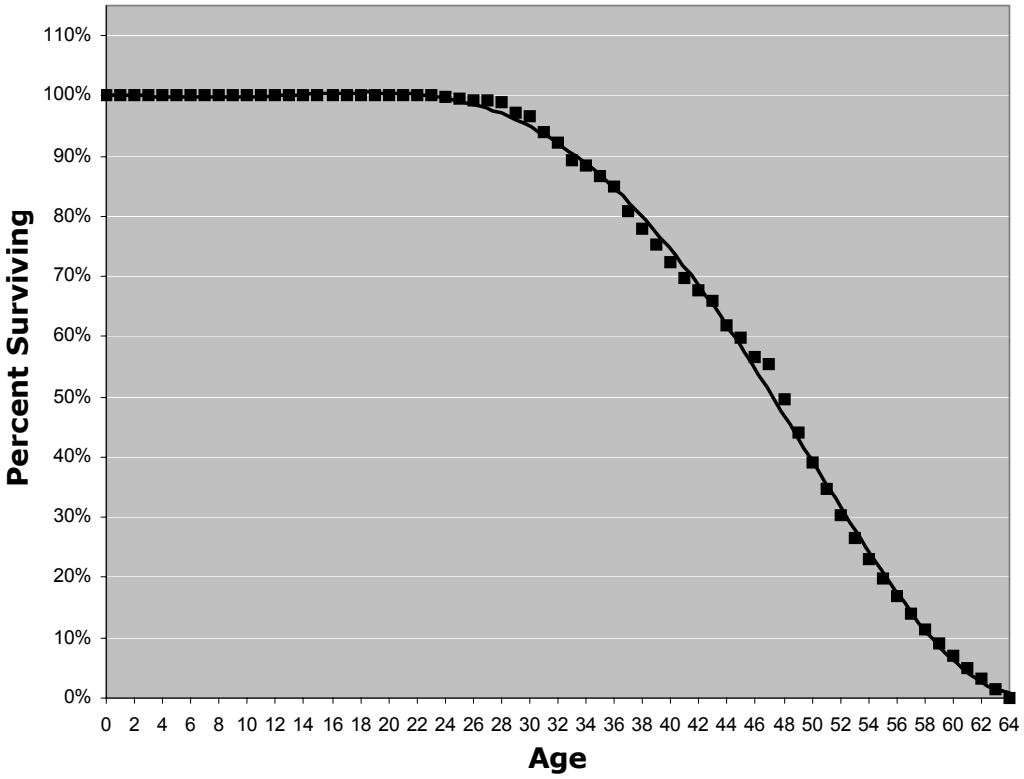
Equipment generally well maintained

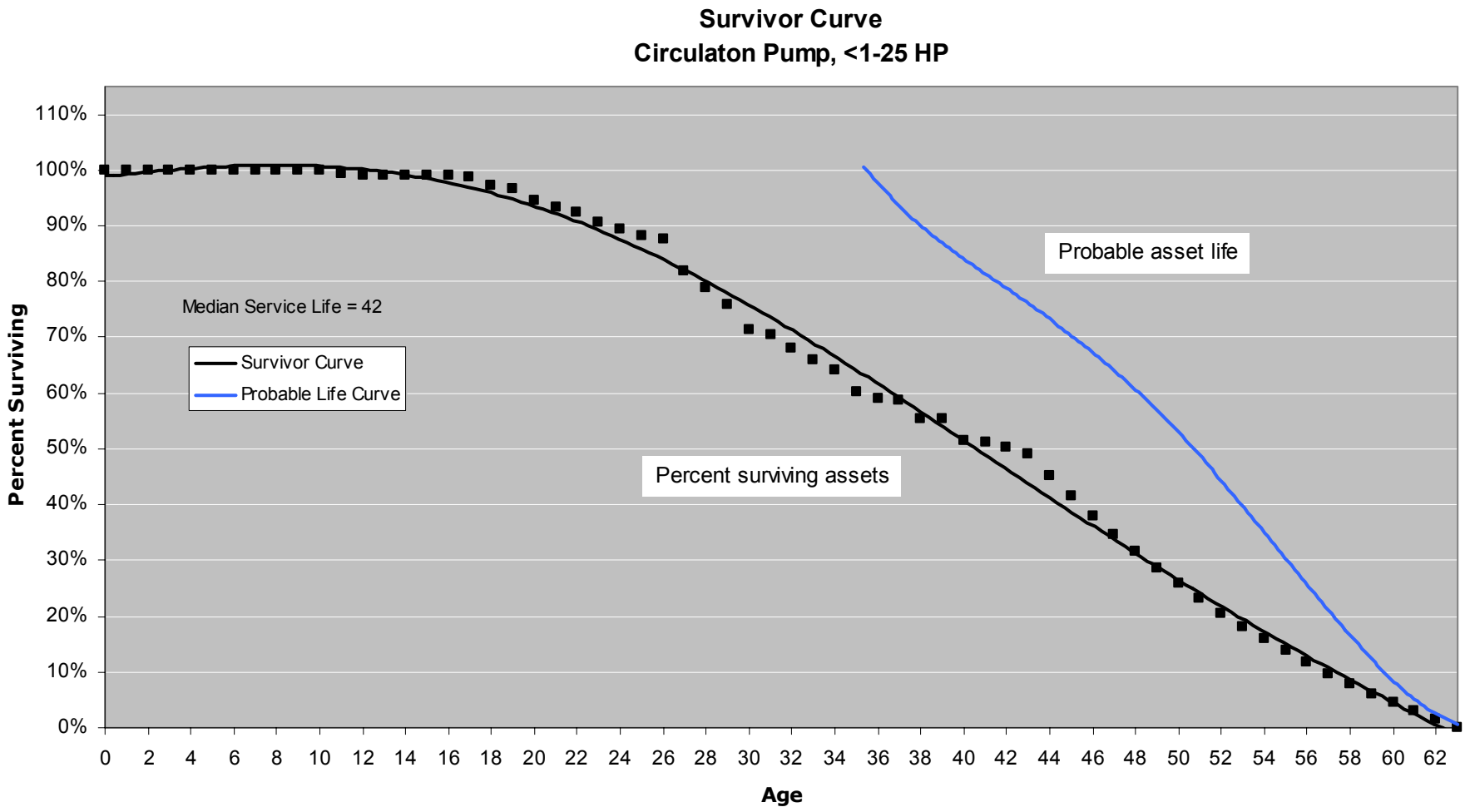
Data sufficient for 12 asset types (Description, individual age, date retired, total assets per type)

DEFICIENCY NUMBER	EQUIPMENT FIELD	TYPE CODE	COMPONENT TYPE DESCRIPTION	LLNL LIFE CYCLE	DOE LIFE CYCLE	YEAR INSTALLED	AGE	YEARS >/Remaining DOE LIFE	YEAR COMPLETED	COMPLETED TYPE	OPTIMUM YEAR
965981	121ACU06-A5	**ACU**	AirHndlr;CentrlSta;Modulr; 5000-10000CFM	25	20	1955	51	**31**			2001
965985	121ACU15	**ACU**	AirHndlr;CentrlSta;Modulr; 5000-10000CFM	25	20	1955	50	**30**	2005	COMP	2001
820600	216ACU37-A1	**ACU**	AirHndlr;CentrlSta;Modulr; 5000-10000CFM	25	20	1942	64	**44**			1999
820602	216ACU39-A1	**ACU**	AirHndlr;CentrlSta;Modulr; 5000-10000CFM	25	20	1942	64	**44**			1999
820612	216ACU63-A1	**ACU**	AirHndlr;CentrlSta;Modulr; 5000-10000CFM	25	20	1942	61	**41**	2003	COMP	1999
820616	216ACU68-A1	**ACU**	AirHndlr;CentrlSta;Modulr; 5000-10000CFM	25	20	1942	61	**41**	2003	COMP	1999
820618	216ACU69-A1	**ACU**	AirHndlr;CentrlSta;Modulr; 5000-10000CFM	25	20	1942	61	**41**	2003	COMP	1999
15387	231ACU28-A7(B)	**ACU**	AirHndlr;CentrlSta;Modulr;33000-42000CFM	25	20	1954	52	**32**			1990
22208	251ACU02-C5	**ACU**	AirHndlr;CentrlSta;Modulr; 5000-10000CFM	25	20	1956	50	**30**			2004
777422	315ACU07-A1	**ACU**	AirCond;FanCoil;ChilledWtr; .5->1.5Ton	25	20	1942	61	**41**	2003	COMP	1999
206582	315ACU09-A1	**ACU**	AirCond;FanCoil;ChilledWtr; .5->1.5Ton	25	20	1942	61	**41**	2003	COMP	1985
206596	315ACU15-A1	**ACU**	AirCond;FanCoil;ChilledWtr; .5->1.5Ton	25	20	1942	61	**41**	2003	COMP	1985

Estimation of Survivor Curves

- Includes data for assets still in service
- Used both polynomial and Weibull functions to fit curves
- Provides distribution in addition to point estimate




Survivor Curve
Circulaton Pump, <1-25 HP
Percent Surviving
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62
Age
Median Service Life = 42
Survivor Curve
Probable Life Curve
Probable asset life
Percent surviving assets

Comparison of LLNL estimates with other standards

Table 2. Service Life Comparison, Selected LLNL Assets

Asset Description	N	CAIS Service Life [A]	LLNL Service Life [A]	Polynomial Median Service Life [B]	Weibull Median Service Life [B]
Self-Contained A/C Unit, 3-60 Ton	60	20	20	24	24
Self-Contained Heat Pump Type A/C, 1.5-50 Ton	1,270	15	15	25	28
Self-Contained Variable Air Volume Type A/C Unit, 1.5-200 Ton	1,147	15	15	25	30
A/C Unit Heating and/or Cooling, 5,000-63,000 CFM	1,464	20	25	41	42
Window or Wall Mounted A/C Unit, 5,000-29,000 BTUH	874	15	15	25	27
Electrical Panel, 120-600 V, 15-4,000 Amp.	3,447	20	40	45	47
Fan Hood Exhaust , 150-34,000 CFM	829	20	20	34	39
Paved Parking Lot, Asphalt, Seal Coat	182	15	20	37	39
Circulator Pump, <1-25 HP	684	20	20	42	42
Refrigeration Condensing Unit, 1.25-30 Ton	286	20	20	31	34
Paved Road, Asphalt, Seal Coat	169	15	20	33	42
Roofing Section, Built-Up, Asphalt Shingles	1,152	20	25	41	42

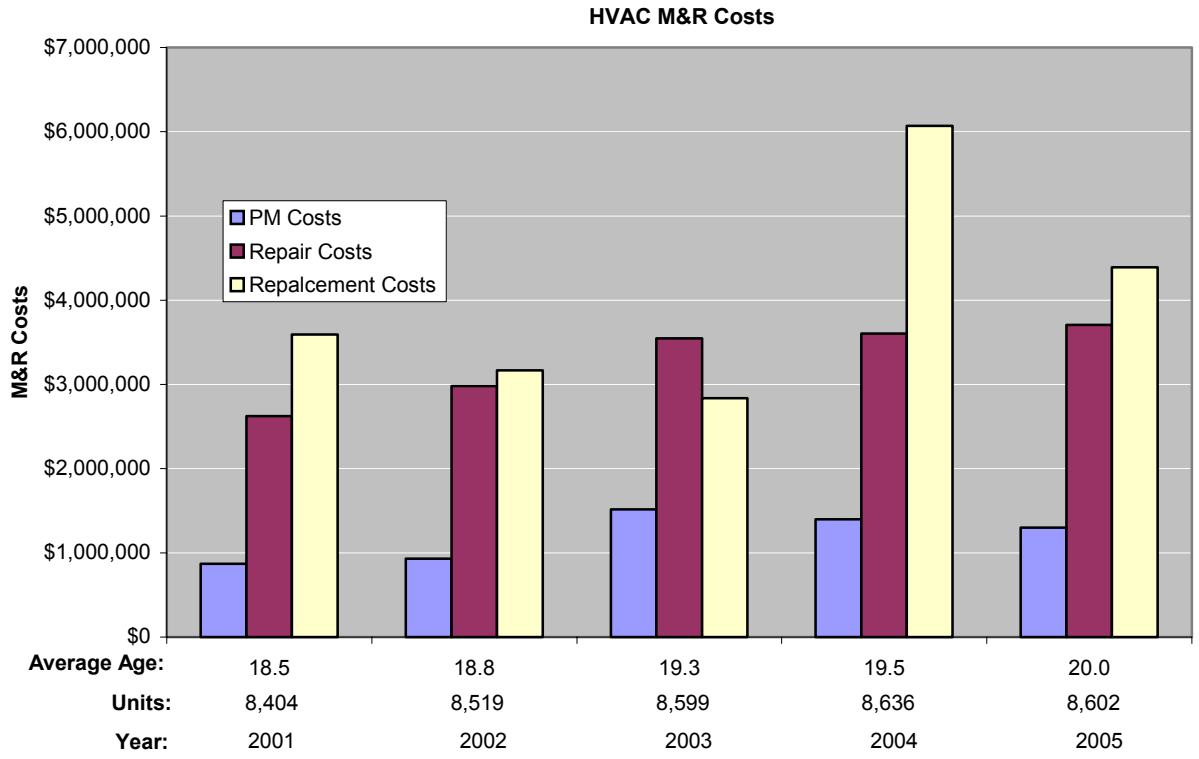
[A] Provided by LLNL.

[B] Median Service Life, the age at which 50% of equipment is still in use.

Contributing factors towards longer LLNL service lives:

- Complete and consistent maintenance schedule
- Regular condition assessments
- Replace equipment on down slope of failure distribution

LLNL M&R costs are relatively level



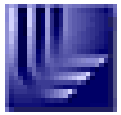
LLNL does not have extended time series or M&R costs for individual assets

Estimated Cost Avoidance for LLNL

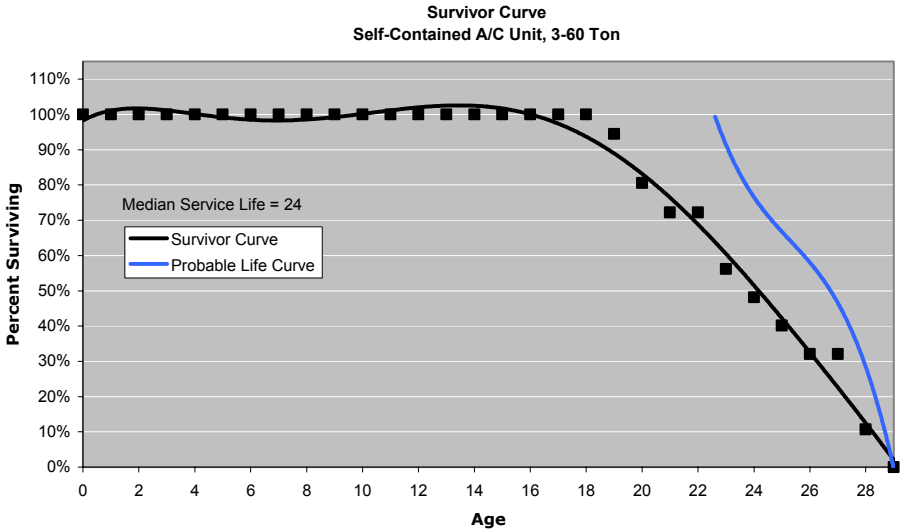
- Equipment replacements exceed CAIS service lives by 66%
  - Cost avoidance = $82.6 M
- Equipment still in service exceeds by 97%
  - Cost avoidance = $181.3 M
- Total estimated cost avoidance = $263.9 M

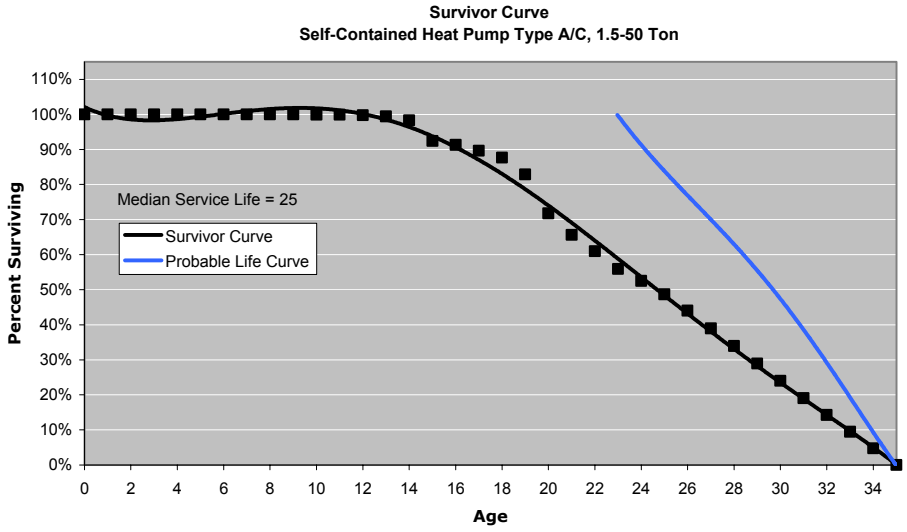
Conclusions

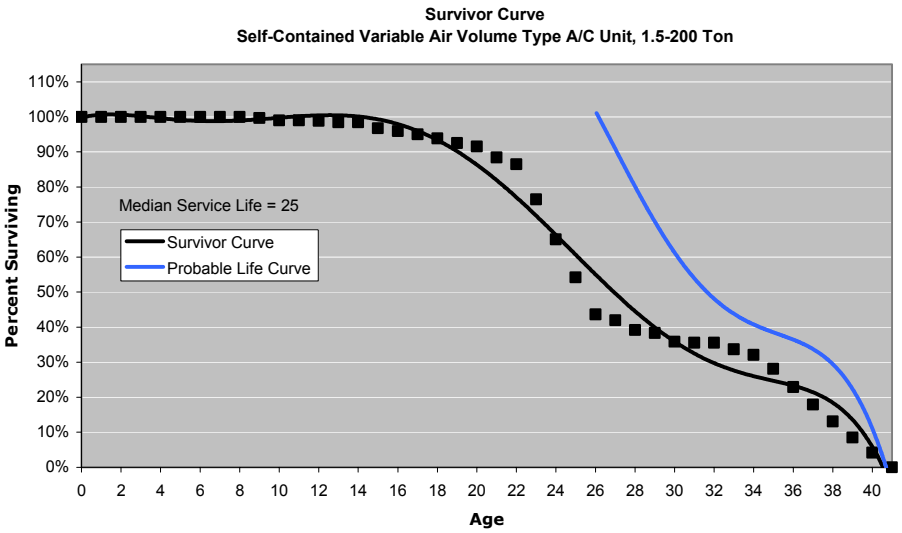
- Costly replacements can be delayed by continued maintenance
- Potential savings are considerable
- Service lives should be re-estimated using actuarial techniques
- Impacts on service call frequency and equipment efficiency unknown
- Case studies needed for detailed life cycle cost analysis

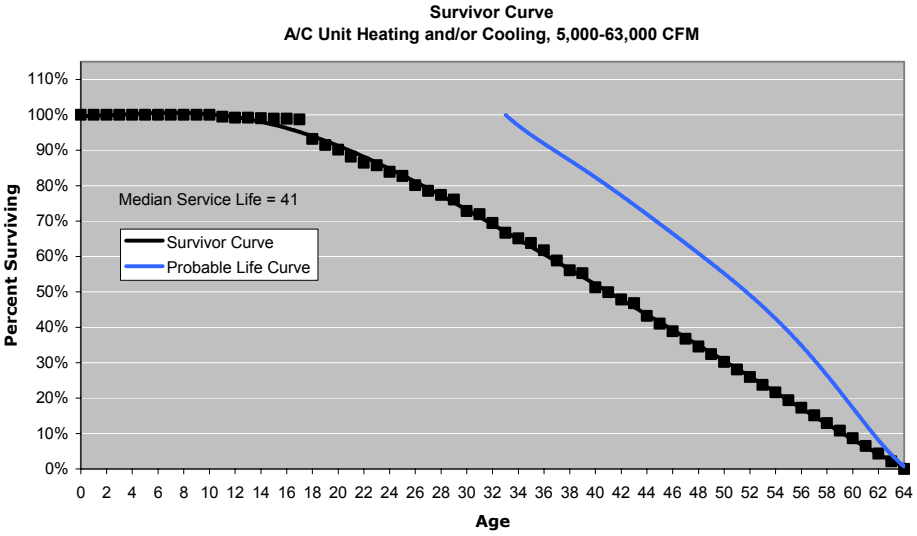


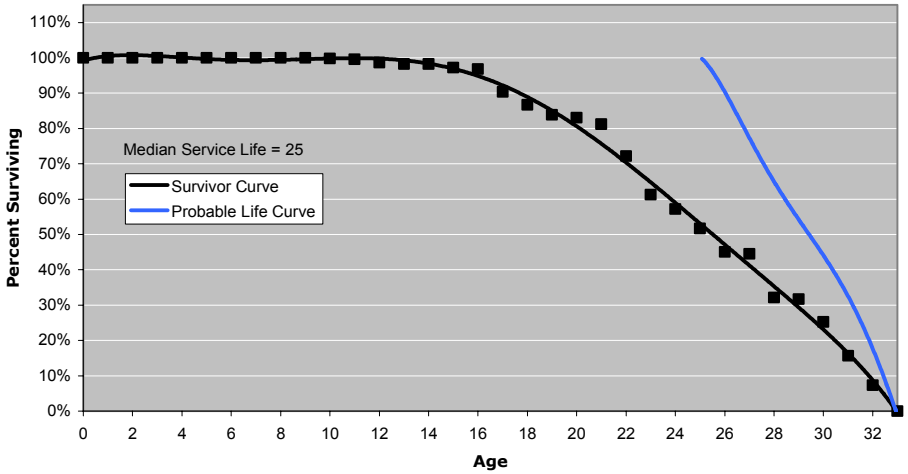
Backup Slides

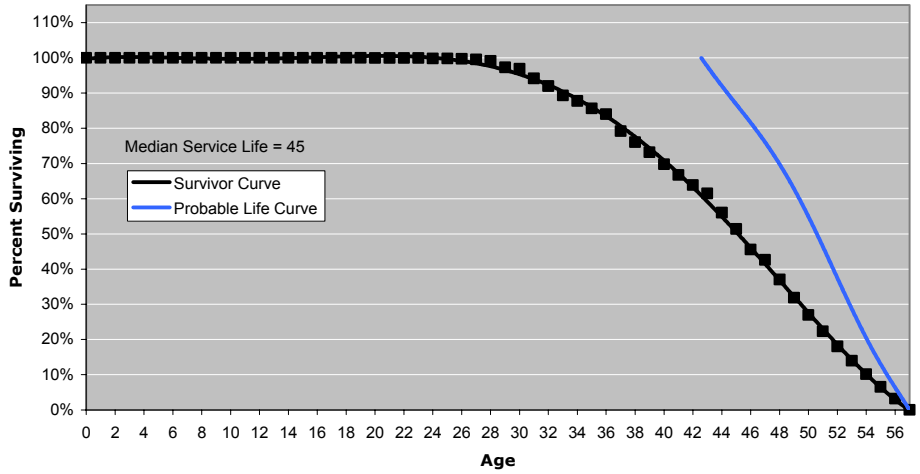

Survivor Curve
Self-Contained A/C Unit, 3-60 Ton
Median Service Life = 24
Survivor Curve
Probable Life Curve
Percent Surviving
Age

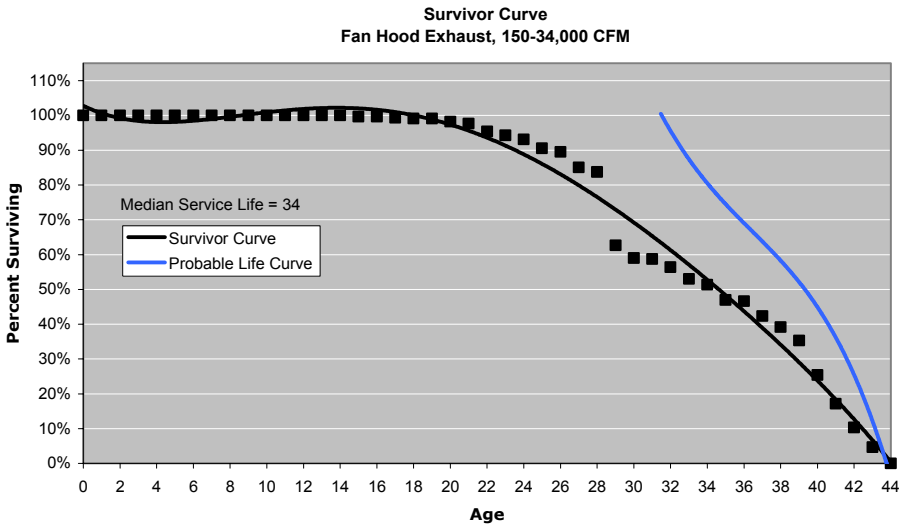

Survivor Curve
Self-Contained Heat Pump Type A/C, 1.5-50 Ton
Median Service Life = 25
Survivor Curve
Probable Life Curve
Percent Surviving
Age

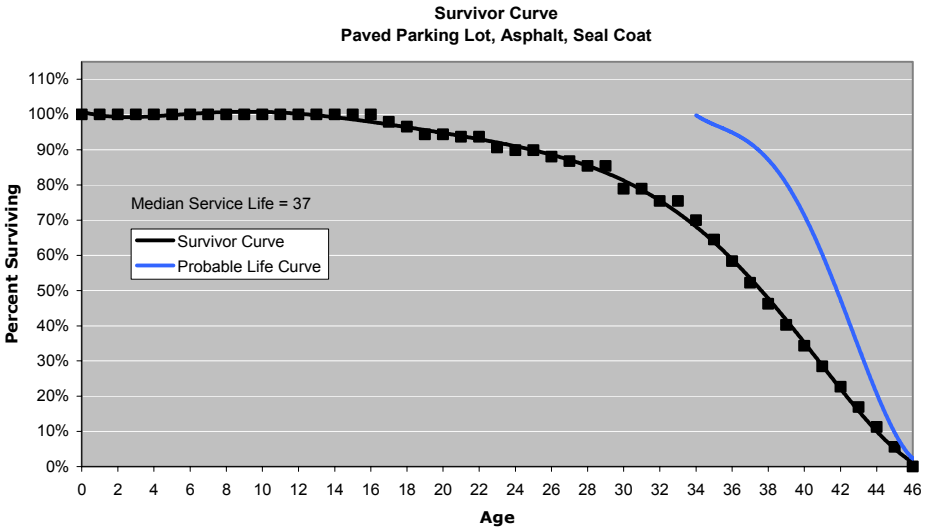

Survivor Curve
Self-Contained Variable Air Volume Type A/C Unit, 1.5-200 Ton
Median Service Life = 25
Survivor Curve
Probable Life Curve
Percent Surviving
Age

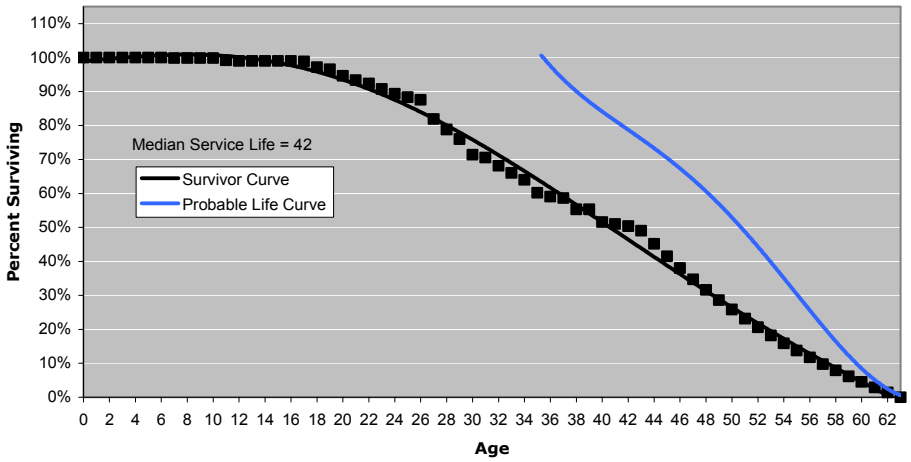

Survivor Curve
A/C Unit Heating and/or Cooling, 5,000-63,000 CFM
Median Service Life = 41
Survivor Curve
Probable Life Curve
Percent Surviving
Age

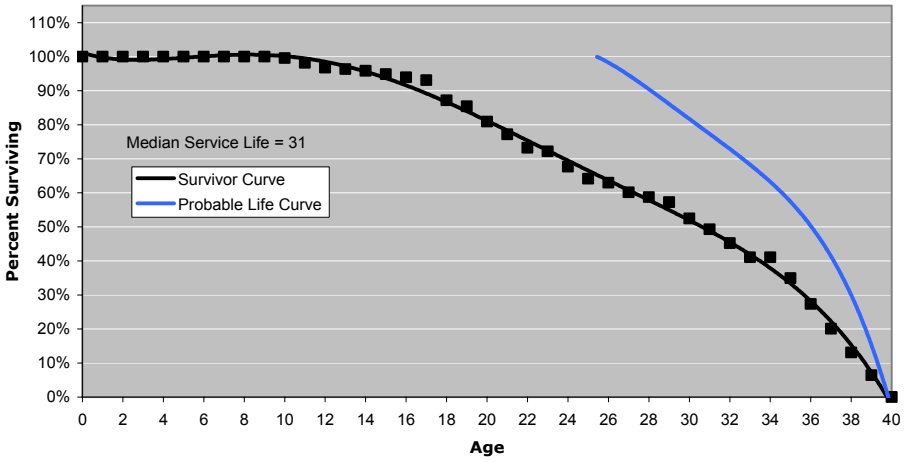

Survivor Curve
Window or Wall Mounted A/C Unit, 5,000-29,000 BTUH
Median Service Life = 25
Survivor Curve
Probable Life Curve
Percent Surviving
Age

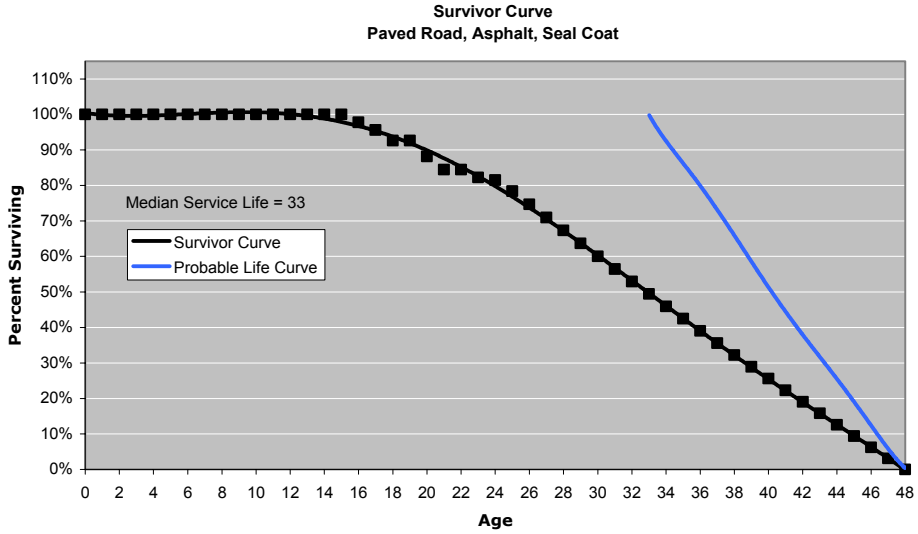

Survivor Curve
Electrical Panel, 120-600 V, 15-4,000 Amp.
Median Service Life = 45
Survivor Curve
Probable Life Curve
Percent Surviving
Age

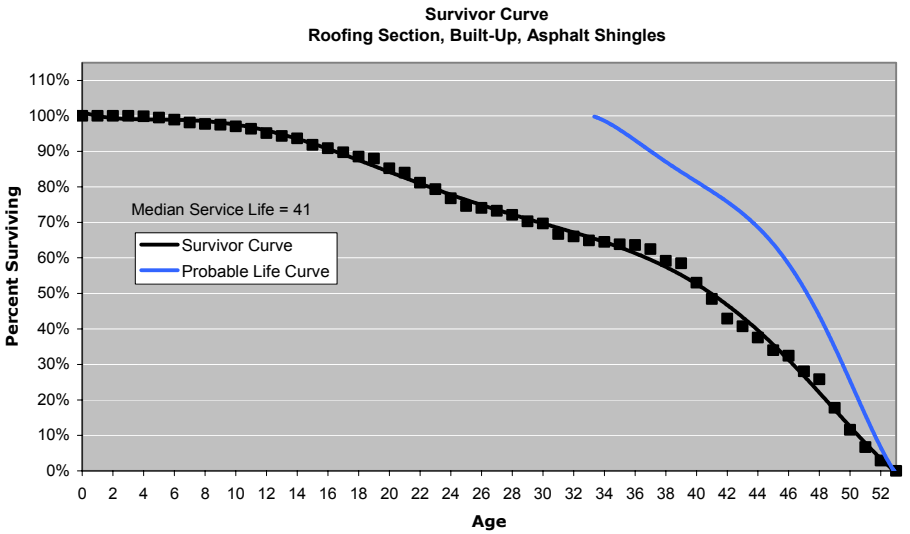

Survivor Curve
Fan Hood Exhaust, 150-34,000 CFM
Median Service Life = 34
Survivor Curve
Probable Life Curve
Percent Surviving
Age


Survivor Curve
Paved Parking Lot, Asphalt, Seal Coat
Median Service Life = 37
Survivor Curve
Probable Life Curve
Percent Surviving
Age


Survivor Curve
Circulaton Pump, <1-25 HP
Median Service Life = 42
Survivor Curve
Probable Life Curve
Percent Surviving
Age


Survivor Curve
Refrigeration Condensing Unit, 1.25-30 Ton
Median Service Life = 31
Survivor Curve
Probable Life Curve
Percent Surviving
Age


Survivor Curve
Paved Road, Asphalt, Seal Coat
Median Service Life = 33
Survivor Curve
Probable Life Curve
Percent Surviving
Age


Survivor Curve
Roofing Section, Built-Up, Asphalt Shingles
Median Service Life = 41
Survivor Curve
Probable Life Curve
Percent Surviving
Age